A r i z o n a

Department of Environmental Quality

LITTLE COLORADO RIVER TMDL FOR TURBIDITY

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United States Environmental Protection Agency

Region 9 The Pacific Southwest

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LIST OF ABBREVIATIONS

ADEQ - Arizona Department of Environmental Quality
ADHS - Arizona Department of Health Services
AGFD - Arizona Game and Fish Department
ALRIS - Arizona Land Resource Information System
AZ - Arizona
BLM - Bureau of Land Management
BMP - Best Management Practices
cfs - Cubic Feet Per Second
EPA - Environmental Protection Agency
ft - Feet
in - Inches
LA - Load Allocation
lbs/day - Pounds per Day
LCR - Little Colorado River
mg/L - Milligrams Per Liter
mgd - Millions of Gallons Per Day
MOS - Margin Of Safety
NTU - Nephelometric Turbidity Units
Q - Discharge
TMDL - Total Maximum Daily Load
TSS - Total Suspended Solids
USEPA- United States Environmental Protection Agency
USFS - United States Forest Service
USGS - United States Geological Survey
WLA - Waste Load Allocation
WQS - Water Quality Standard

EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act requires that States develop Total Maximum Daily Loads (TMDLs) for surface waters that do not meet, and maintain, applicable water quality standards (WQSs). A TMDL sets the amount of a given pollutant that the water body can assimilate without creating an impairment of that surface water's designated use. The TMDL by definition (40 CFR Part 130) is the sum of all Waste Load Allocations (WLAs) (point sources) and Load Allocations (LAs) (non-point sources) with the inclusion of a margin of safety (MOS) and natural background conditions.

The Little Colorado River (LCR) is located in southern Apache County, AZ near the border with New Mexico. Its headwaters originate in the White Mountains along the northern and eastern slopes of Mount Baldy (11,043 feet (ft.)) (Fig. 1). The river flows east-northeast until it reaches Eagar, AZ where it turns to a more northerly course. Two segments, totaling 16 miles, of the LCR, near Springerville, AZ, were listed as impaired due to violations of the turbidity standard for Aquatic and Wildlife coldwater streams, which is 10 NTU. The first segment, Water Canyon Creek to Nutrioso Creek (HUC 15020001-010), is 4 miles long. The second segment, Nutrioso Creek to Carnero Creek (HUC 15020001-009), is 12 miles long.

The LCR was placed on the 303(d) List based on sampling taken from 1991 through 1996 (see Table 1). From June to October 2000, the Arizona Department of Environmental Quality (ADEQ) conducted an intensive turbidity study of the LCR. Eighteen monitoring sites were established along the LCR from the intersection of Highways 260 and 373 (near Greer) to the end of the listed reach. The results indicate that the turbidity impairment actually starts upstream of the confluence of the LCR with Water Creek Canyon (Site 35). Field observations indicated that the main cause of turbidity is loss of vegetative cover due to historic and current grazing practices. The loss of vegetation, especially riparian, allows increased runoff, soil erosion, and bank destabilization.

The turbidity impairment appears to be directly correlated to large flow events that occur during the Winter-Spring rain/snowmelt season and during the Summer-Fall monsoon season. These correlations were developed based on United States Geological Survey (USGS) historic flow data for the LCR. TMDL values were developed for each season to reflect these differences in flow regimes and resultant sediment delivery mechanisms. Because turbidity is a dimensionless unit, site specific TSS versus turbidity correlations were created for this TMDL. These correlations link TSS values in milligrams per liter (mg/L) to turbidity standards and measurements. Target Load Reductions of TSS will equate to reductions of turbidity.

Table 1 Summary of Turbidity Data on LCR Used to Make Listing Decision

Segment	Agency Program Site Description	Year - Number of Samples	Results Range[1] (NTU)	Samples Exceeding Standards (Exceedance Rate)
Water Canyon - Nutrioso Creek	ADEQ FSN Hwy 60 Bridge (TMDL sample site 90)	1994 - 6 1995 - 6 1996 - 6	7.06 - 96.4	12 of 18 (67% exceedance)
Nutrioso Creek - Carnero	ADEQ Biocriteria Below Nutrioso	1992 - 1	16.2	1 of 1 (100% exceedance)
	ADEQ FSN Below Springerville	1991 - 5 1992 - 6 1993 - 3	3.9 - 47	7 of 14 (50% exceedance)

1 TheWQS for turbidity is10 NTU.

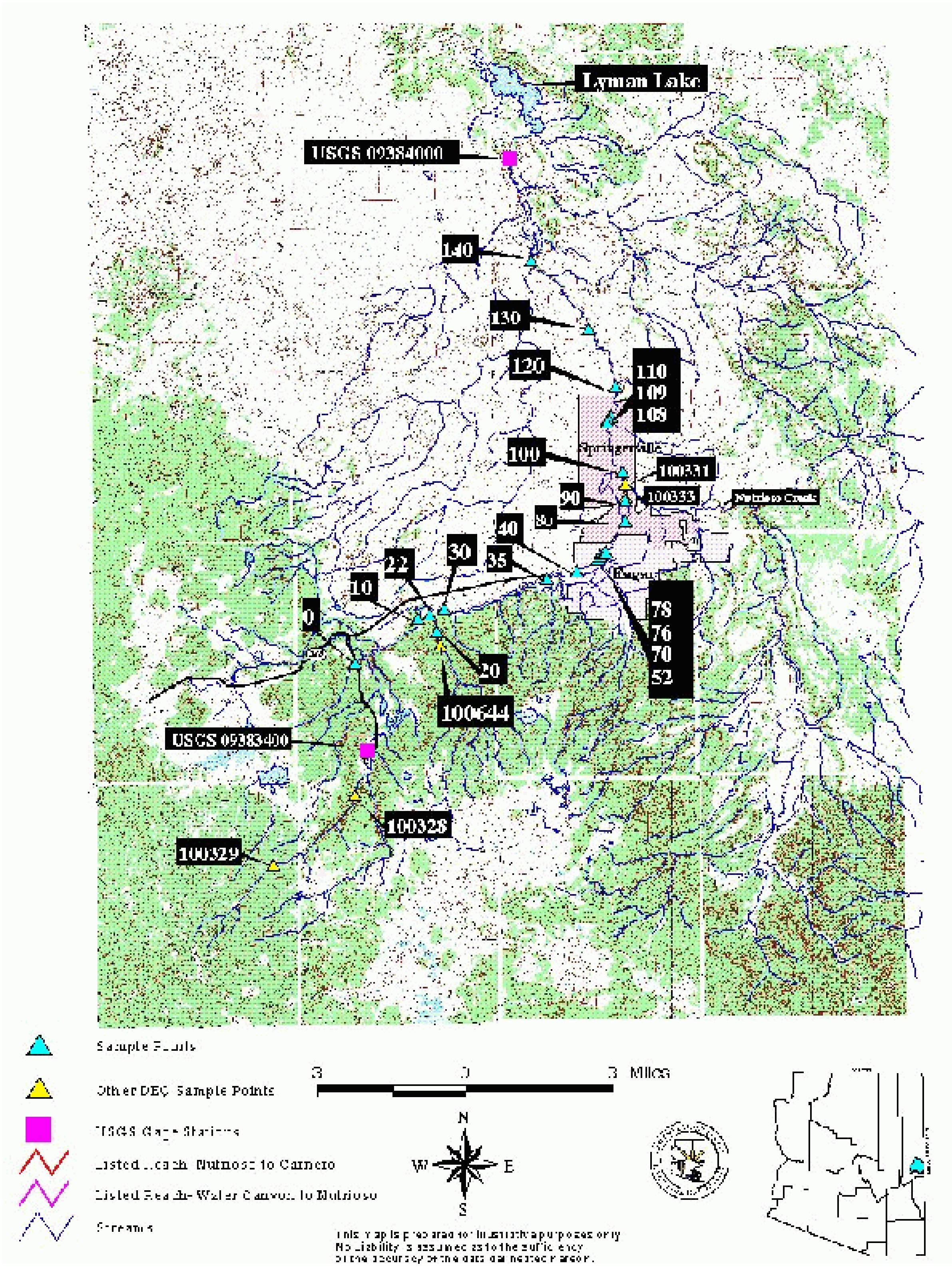
The target load capacity for the LCR during the Winter-Spring seasonal flows (28.9 cubic ft. per second (cfs)) was calculated to be 1,702 pounds per day (lbs./day) as Total Suspended Solids (TSS) (Table 2). The Measured Load was estimated to be 6,959 lbs./day. Using a 10% explicit MOS, the Load Reduction necessary is 5,257 lbs./day. During the Summer-Fall seasonal flows (13.1 cfs), the target load capacity was calculated to be 681 lbs./day. The Measured Load is 2,509 lbs./day. Using a 25% MOS, the Load Reduction necessary is 1,828 lbs./day.

Table 2 TMDL Summary Table For The Little Colorado River

WINTER-SPRING FLOWS (FEB-MAY)		SUMMER-FALL FLOWS (JUN-SEP)	
Designed for 28.9 cfs (18.9 mgd)		*Designed for* 13.1 cfs (8.5 mgd)	
Background, lbs./day TSS	354	*Background, lbs./day TSS*	354
Waste Load Allocation, lbs./day TSS	0	*Waste Load Allocation, lbs./day TSS*	0
Load Allocation, lbs./day TSS	1,225	*Load Allocation, lbs./day TSS*	262
Margin of Safety, lbs./day TSS	123	*Margin of Safety, lbs./day TSS*	65
TMDL, lbs./day TSS	1,702	*TMDL, lbs./day TSS*	681
Measured Load, lbs./day TSS	6,959	*Measured Load, lbs./day TSS*	2,509
Load Reduction, lbs./day TSS	5,257	*Load Reduction, lbs./day TSS*	1,828

Implementation projects and best management practices (BMPs) should be aimed at decreasing the contributions of sediment during higher flow events. Effective methods include increasing riparian vegetation, stream bank stabilization, promotion of flood plain development, and minimization of the impact of cattle in the general area. This can be accomplished by watershed improvements on uplands and riparian areas, road maintenance or closures, and improved grazing strategies and practices.

Figure 1 Project Area



1 BACKGROUND INFORMATION

1.1 Geography

The LCR is located in southern Apache County, AZ, near the border with New Mexico. The headwaters originate in the White Mountains along the northern and eastern slopes of Mount Baldy (11,403 ft.) (Fig. 1). The river flows east-northeast until it reaches Eagar, AZ, where it turns to a more northerly course.

1.2 Geology

The rugged upper part of the watershed near Mount Baldy is mid to late Tertiary volcanics (Reynolds, 1988). The listed reach flows mainly through upper Tertiary and upper Quaternary volcanics (Reynolds, 1988). The area is also the site of the Springerville volcanic field, which contains over 380 cinder cones and flows (ASU, 2001). Soils in the study area generally fall into three categories: 1) sandy on steep slopes around Greer; 2) shallow, basaltic, and stony near the South Fork confluence; 3) alluvial, with higher clay concentrations in the Springerville/Eagar vicinity (ADEQ, 1982).

1.3 Hydrology

The LCR watershed above Lyman Lake drains approximately 774 square miles (Arizona Department of Health Services (ADHS), 1982). The LCR is a perennial stream that responds primarily to two seasonal events: a Winter-Spring snowmelt and rain season from February to mid-May and a Summer-Fall monsoon event season from June through September. Two USGS gauge stations are present on LCR. USGS gage # 09384000 is located above Lyman Lake, near St. John's, AZ, and USGS Gage # 09383400 is located near Greer, AZ. The major tributaries to the LCR are South Fork, Grapevine Creek, Water Canyon Creek, Nutrioso Creek, and Carnero Creek. The stream portions above the confluence with South Fork are generally steep and store little sediment. Below the confluence with South Fork, the gradient and steam velocity decreases.

Data from over 60 years of record (1940 to 2000) for USGS gage station #09384000, above Lyman Lake, were used to calculate the average flow for each day of the year. Winter –Spring season (Nov 1 to May 31) flow values average 28.9 cfs. The average flow for the Summer-Fall season (Jun 1 to Oct 31) is 13.1 cfs. The average base flow was also calculated and found to be 11.0 cfs, however the calculations were not carried over to the average base flow value, because these Winter-Spring and Summer-Fall TMDL values represent the critical condition for the LCR for sediment and, thus, turbidity impairments.

1.4 Climate

Climate varies greatly throughout the reach. The higher elevations generally receive more precipitation (annual average of 23.39 inches (in.) near Greer, AZ and 12 in. near Springerville, AZ). Precipitation is primarily rain and snow in the higher elevations and rain in the lower elevations. Summers in the higher elevations are warm in the day, averaging a maximum of 76Ein July, and cool at night, averaging a minimum of 47Ein July. Summers in the lower elevations are often hot, averaging a maximum of 82-90Ein the day and, at night, averaging a minimum of 51-57Ein July.

1.5 Vegetation

The LCR transects many ecosystems (Fig. 2). Vegetative species are predominantly spruces and firs above 9,500 ft., ponderosa pines and mixed conifers above 8,000 ft, and pinon pine/juniper and grasslands at the lower elevations. A very marked transition between the pines and the grasslands occurs around 7,400 ft. (ADHS, 1982).

1.6 Land Use

According to the land ownership information provided by Arizona Land Resource Information System (ALRIS), the LCR watershed is a mixture of Federal, State, and private lands (Fig. 3). Land ownership is comprised of 45% United State Forest Service (USFS) Apache-Sitgreaves National Forest lands, 37% Arizona State Trust lands, and 17% private party ownership. The remaining 1% is Arizona Game and Fish Department (AGFD), Bureau of Land Management (BLM), and White Mountain Apache lands. The major land use along the listed reach is agriculture and open range. Figure 4 shows land use type and percentage of total area.

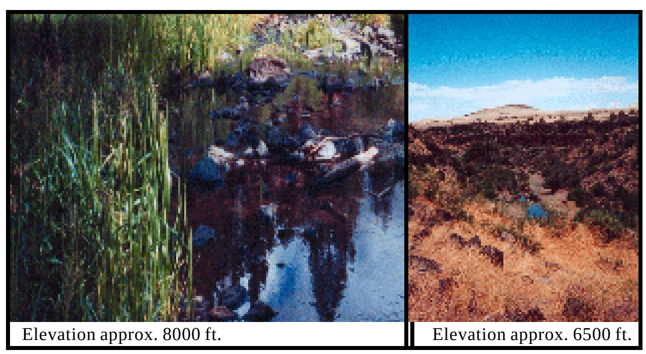


Figure 2 Representative Ecosystems

Figure 3 Land Ownership

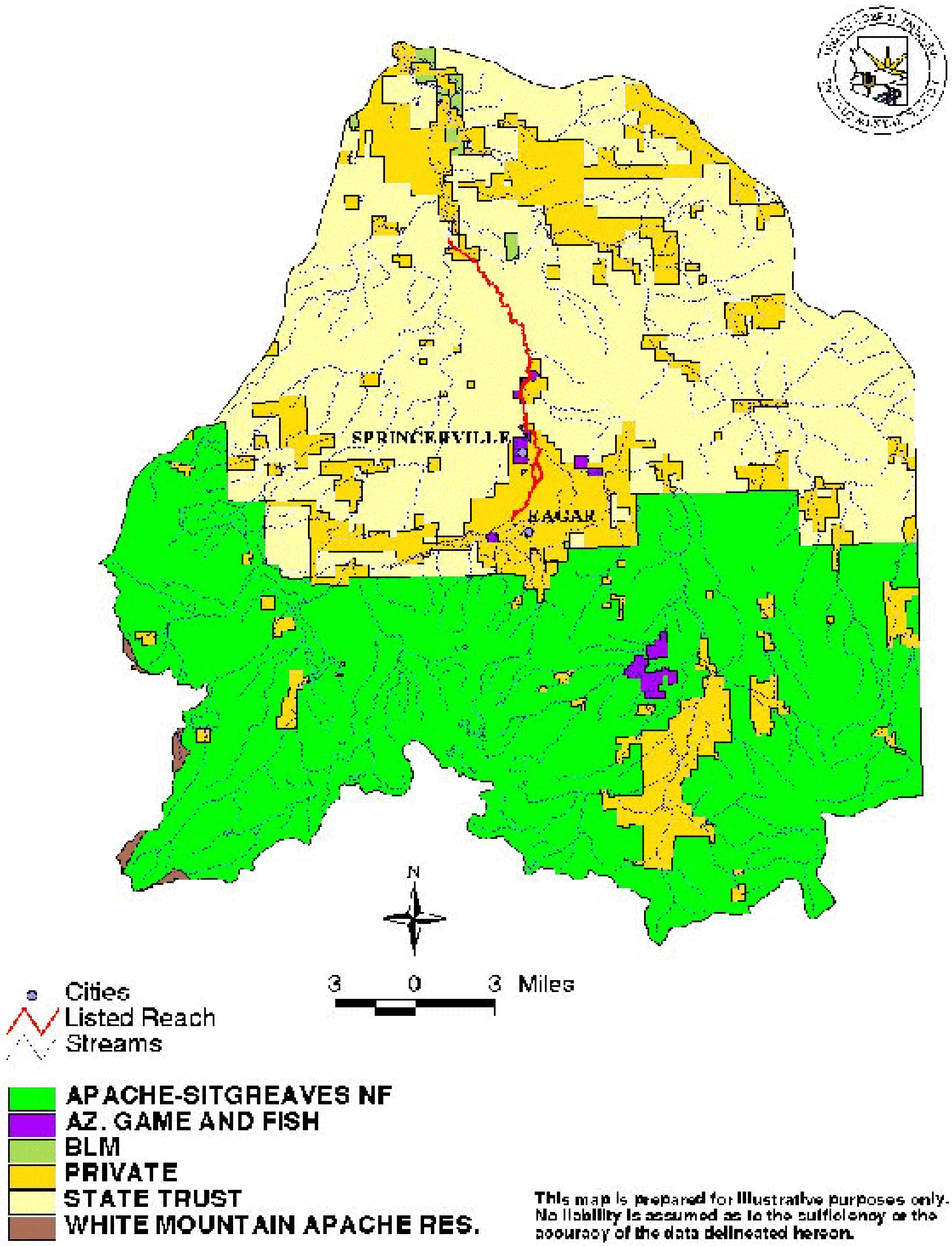
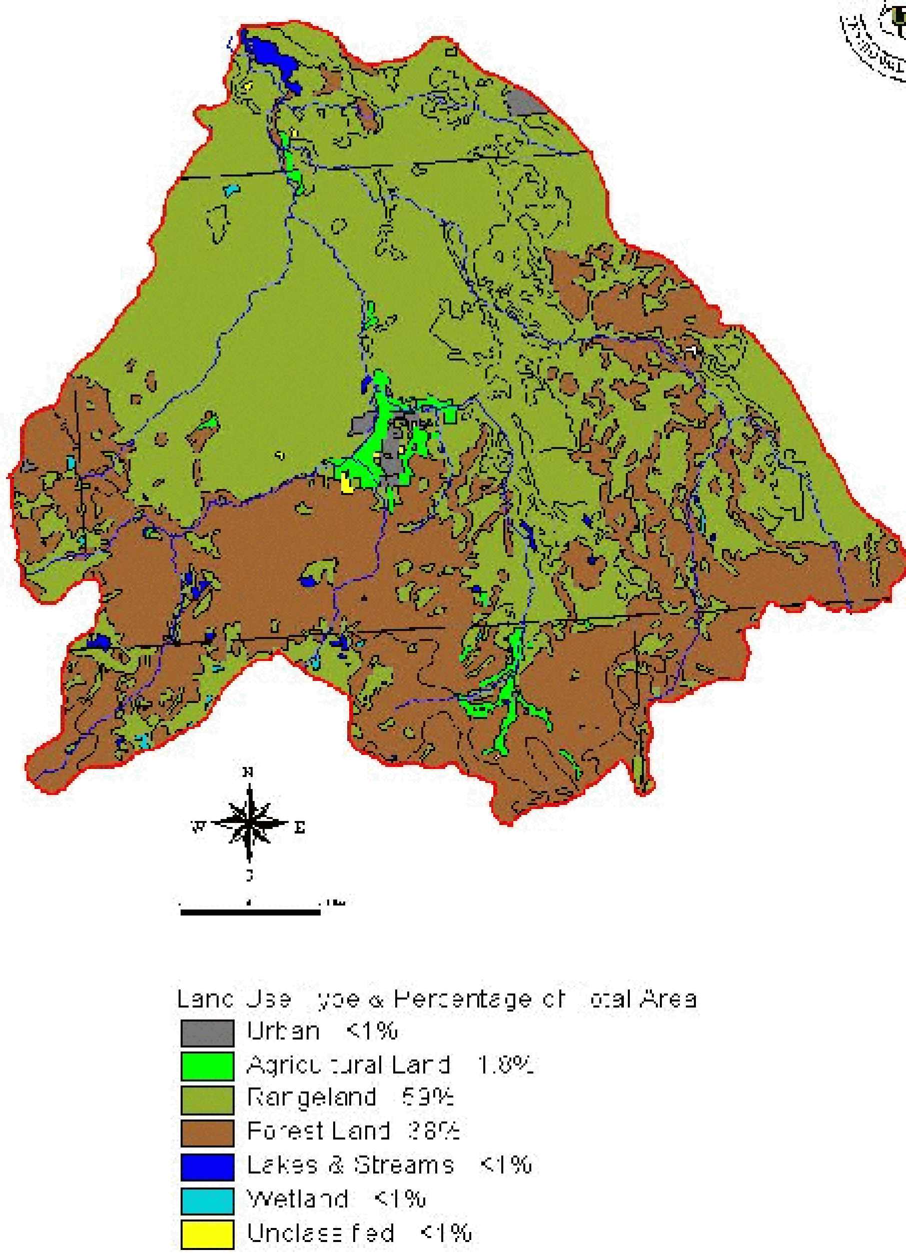


Figure 4 Land Use



This map is prepared for illustrative purposes only. No liability is assumed as to the sufficiency or the accuracy of the data delineated hereon.

2 ENDPOINT IDENTIFICATION

2.1 Turbidity and the Linkage of Water Quality Standards and Pollutants

The United States Environmental Protection Agency's (USEPA's) recommended approach to the development of TMDLs with limited data is to develop estimates comprised of the best methods and data available (USEPA, 1999).

Turbidity is a measure of the refraction of light, caused by the scattering of the photons, as it passes through a sample of water. Although this can be due to a variety of causes, the turbidity standard was created as an indirect measure to protect aquatic life from impacts due to excessive sedimentation and excessive algal blooms.

2.2 Identification and Description of Pollutant Sources

In the 1998 303(d) list, the LCR is listed as impaired for turbidity from Water Canyon Creek to Carnero Creek (ADEQ, 1998) (Table 1). From June to October 2000, ADEQ conducted a turbidity study of the LCR. Eighteen monitoring sites (Fig. 1) were established from the intersection of the Highways 260 and 373 (near Greer) and the LCR (Site 0) to the end of the listed reach (Site 140). The sample sites were selected to better define sources of turbidity. Sample results are included in Appendix A. The results indicate that the turbidity impairment actually starts upstream of the confluence with Water Creek Canyon (near Site 35).

2.2.1 Point Sources

No point sources were found on the LCR during ADEQ's investigations. There have been no National Pollutant Discharge Elimination System (NPDES) permits issued for this stretch of the river system.

2.2.2 Non-Point Sources

The turbidity impairment in the LCR is a result of excessive sediment from natural and anthropogenic sources that is flushed into the LCR system. A number of possible sources were identified during the field investigations.

2.2.2.1 Grazing and Wildlife

Ungulate grazing can contribute sediment to the system by disruption of the soil surface, soil compaction, removal of organic matter, and trailing. When ungulates overuse an area, there is the potential for increased soil loss, compaction, and accelerated overland flow. In riparian areas, grazing can reduce riparian vegetation, destabilize banks, and cause in-stream disturbances that reduce the functionality of the stream.

The free range grazing practices of the turn of the century had drastic impacts on the soil and vegetation of the LCR watershed (ADEQ, 2000).

Today, livestock still graze most of the watershed. Even though grazing practices have improved, improper livestock grazing is a source of fine grained sediment.

2.2.2.2 Stream Channel Instabilities

This portion of the LCR also suffers from a lack of riparian vegetation. The absence of vegetation in the stream course, which naturally slows the flow, contributes to higher velocities during high flows (Snyder, 1994). This causes down cutting of the stream. Down cutting of the channel creates a loss in flood plain for the stream which means that during high flows, like the critical flows, stream velocities are increased, thus increasing the shear stress/force acting upon the stream banks and increasing the erosional forces.

2.2.2.3 Road Systems

The USFS is mandated to maintain its system roads to certain standards. However, non-system roads created by recreationists undermine USFS efforts. The USFS expends much effort on closing non-system roads and reducing off-road travel; however, adequate funding is not always available. Other public roads are also a source of sediment. Road cuts, bridges, culverts, and other transportation features also impact the LCR.

2.2.2.4 Golf Course

The recent construction of a golf course on the LCR (Sites 70, 76, and 78) contributed sediment to the river. The golf course received a notice of violation from the ADEQ for violation of the surface WQS for turbidity. The golf course altered construction practices and implemented other BMPs to control sediment delivery to the LCR. Even though the golf course construction has been completed, there are several stretches of river within the property boundaries that would benefit from stream stabilization restoration.

2.2.2.5 Natural Conditions

Natural sediment contributions can be the result of geologic formations and processes and their interactions with the vegetation, soils, and wildlife. In addition to out-of-stream contributions, fine sediment which has been stored within the void spaces of larger bed materials, and flood plains and point bars, can be a source of turbidity. During large flow events, these fine sediments are re-suspended and transported further down the system. Organic suspended materials and organisms present in the water column can also effect the turbidity readings themselves by scattering the light of the turbidity meter in the same manner as suspended solids.

2.3 TMDL Calculation

Turbidity is not easily transferred into the TMDL framework because it is a dimensionless unit. Because of this, site specific TSS versus turbidity correlations were created for this TMDL. These correlations link TSS values in mg/L to turbidity standards and measurements. Target Load Reductions of TSS will equate to reductions of turbidity. This is useful as the increased turbidity during high flows is caused by higher TSS due to increased stream water velocities, shear stress, and stream power, which all result in higher erosional forces.

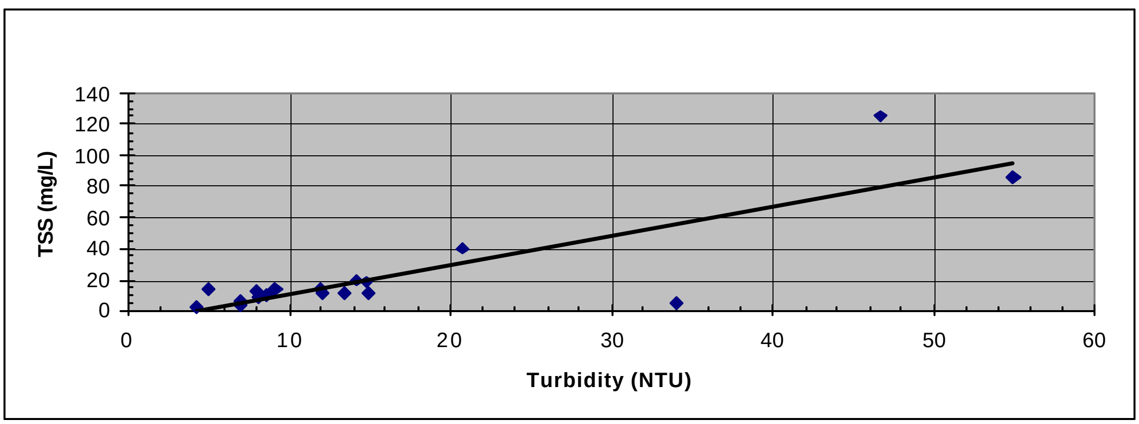
2.3.1 TSS Equations

The correlation graphs, and the resulting equations, are based on data obtained through field measurements, laboratory results for TSS, and historic records. This correlation allows a numeric estimate of the amount of sediment and turbidity present in the stream during critical flows. Two sets of data were created: a Winter-Spring set and a Summer-Fall set. This allows for the creation of a set of regressions and correlations that better represent seasonal conditions, and allow for the creation of more valid regressions between the data points. The average flow values were used to calculate a corresponding turbidity and TSS reading by utilizing the Turbidity & TSS vs. Discharge graphs and the TSS vs. Turbidity graphs.

Taken from the solution to the line best fitting the data in Figure 5, Winter-Spring, TSS vs. Turbidity

$TSS=1.8726(turbidity) – 7.8851, R^2=0.7008$ Equation 1

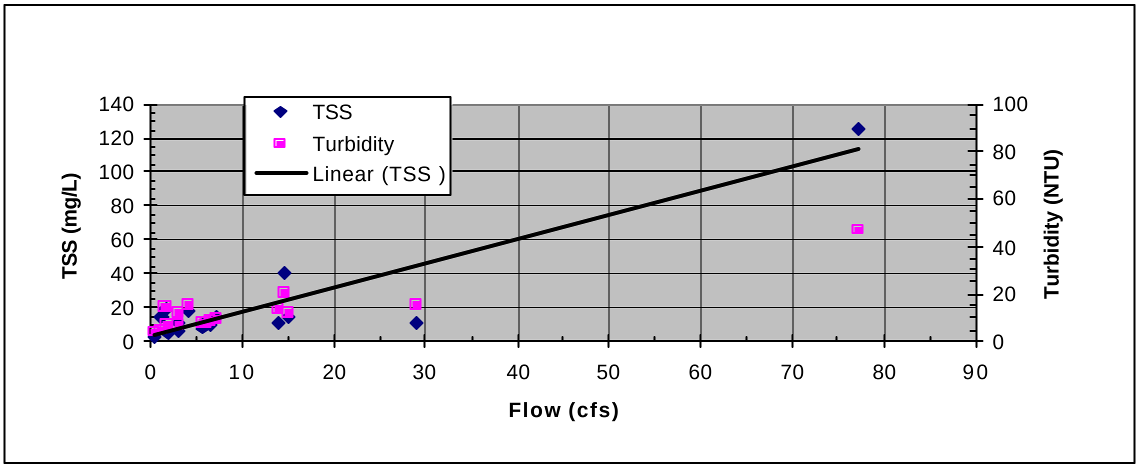
Figure 5 Winter-Spring, TSS vs. Turbidity



Taken from the solution to the line best fitting the data in Figure 6, Winter-Spring, TSS and Turbidity vs. Flow

$TSS = 1.4232(Q) + 3.0976, R^2=0.8327$ Equation 2

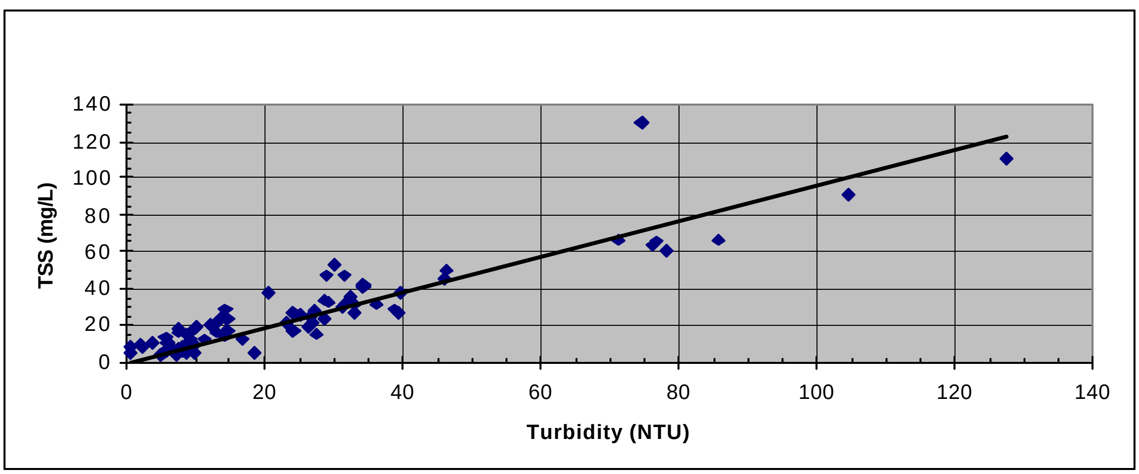
Figure 6 Winter-Spring, TSS and Turbidity vs. Flow



Taken from the solution to the line best fitting the data in Figure 7, Summer-Fall, TSS vs. Turbidity

$$TSS=0.9644(turbidity), R^2=0.8055$$ Equation 3

Figure 7 Summer-Fall, TSS vs. Turbidity

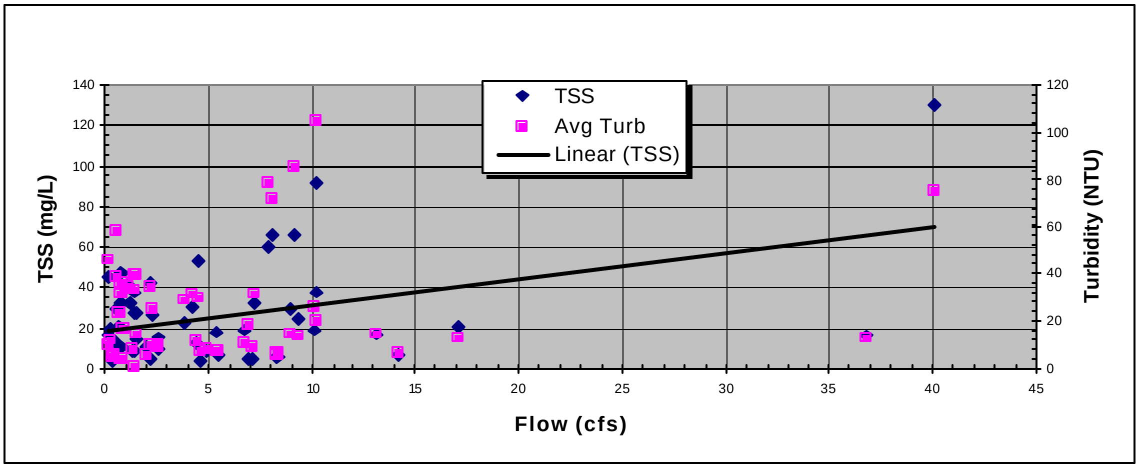


Taken from the solution to the line best fitting the data in Figure 8, Summer-Fall, TSS and Turbidity vs. Flow

$$TSS = 1.2616(Q) + 18.874, R^2=0.1682$$ Equation 4

Figure 8 Summer-Fall, TSS and Turbidity vs. Flow

2.



3.2 Background Site Location and Values

In order to determine the natural background sediment load value, a search was conducted to identify another watershed consisting of the same geography, geology, hydrology, vegetation, channel morphology, and watershed size as the LCR watershed. Criteria for the search included:

1.) The potential site must lie within, or tributary to, the LCR watershed

2.) Must be an unlisted (303(d)) water body for exceedances of the surface water quality turbidity standard

3.) It should have no, or few, anthropogenic disturbances within it's watershed boundary

4.) There should be a sufficient amount of TSS and discharge data to perform the necessary calculations

No suitable site could be found that was near the same watershed size or flow regime as the LCR. Therefore, the search was modified to identify any relatively undisturbed, or unlisted, segment within the watershed, or a tributary to the LCR, that could be used to approximate natural background values. A section of the LCR was used to calculate the natural background values. The natural background conditions for sediment for the LCR were estimated by using two sampling locations upstream of identified nonpoint sources, and above the 303(d) listed segments of the LCR. These sample stations, 10 and 30 (Fig. 1), maintain the same geologic, hydrologic, and geomorphic conditions as the listed reach of the LCR. The channel is approximately the same size, and flows at the sampling stations correspond well to flows in the main channel of the listed segment. To arrive at a value for the background load for sediment, the turbidity values from these sampling stations were averaged and correlated into a Total Suspended Solids value, and then calculated into a daily load.

The average of the turbidity readings taken by ADEQ at these sample stations through the TMDL sampling plan, was 6.2 NTU. These values were taken in the summer-fall season, so Equation 3 was used to calculate the corresponding TSS concentration of 5.9 mg/L. To convert the 5.9 mg/L into a daily load value for TSS, 5.9 mg/L TSS was input into the following equation.

Flow (mgd) x average ***TSS*** (mg./L) x 8.34[1] ***= Background, TSS*** (lbs./day)

TABLE 3 CALCULATION OF BACKGROUND VALUE

Flow (cfs)	***Flow (mgd)***	***TSS (mg/L)***	***Background, TSS (lbs./day)***
11.0[2]	7.2	5.9[3]	**354**

1 8.34 is a conversion factor to transform mg/L to lbs./day, the units are (lbs.)(L)/(mg)(10^6 gallons)

2 Average flow values taken from USGS Gage Station 09384000, from 1940-2000

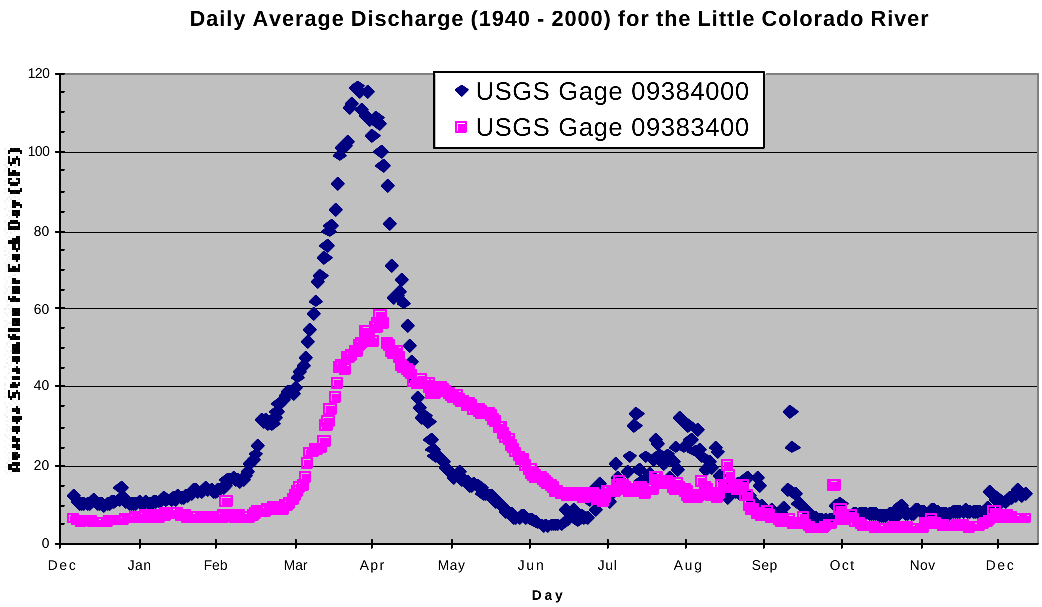
3 Calculated value based on turbidity samples

2.3.3 Consideration of Seasonal Variation

The LCR experiences three distinct flow regimes (Fig. 9): a Winter-Spring snowmelt and rain season, a Summer-Fall monsoon storm season, and the base flow conditions that occur at other times of the year. For this report data was sorted into two categories, Winter-Spring season, and Summer-Fall season. The Winter-Spring data has higher overall flows, a larger contributing sediment load, and is more sustained over the duration of the season. The Summer-Fall monsoon storm driven flows are highly variable dependent on location and storm intensity.

To take into consideration this discharge variation, and address the differences in the correlations between TSS and turbidity and flow, the TMDL values were calculated for each season. The average flow values were used to calculate a corresponding turbidity and TSS reading by utilizing the TSS and Turbidity vs. Discharge graphs (Figs. 6 and 8) and the TSS vs. Turbidity graphs (Figs. 5 and 7).

Figure 9



2.3.4 Margin of Safety

The MOS for this TMDL is different for the two seasons due to uncertainty in the correlations and regression analysis. For the Winter-Spring season, where a relatively sound regression was created between TSS and turbidity, and TSS and discharge, the MOS was set to be 10% of the LA value. For the Summer-Fall season, where a relatively sound regression was created between TSS and turbidity, but a large amount of scatter created an unreliable relationship between TSS and discharge, the MOS was set to be 25% of the LA value. These explicit MOS values account for errors in calculating the critical and average flows, the innate errors present in the correlation of TSS and turbidity with discharge, the possible error in the estimate of natural background values, and for the accuracy of the measurements and instruments.

2.3.5 Winter-Spring Flow Based TMDL Values

The following TMDL calculations are based upon the average Winter-Spring flow value of 28.9 cfs, which is based on 60 years of available data from the USGS gage station above Lyman Lake.

Calculation of Target Load Capacity (lbs, of TSS per day) for Winter-Spring Flows
Flow (mgd) x ***TSS target*** (mg/L) x 8.34[1] = ***Target Load*** Capacity, TSS (lbs./day)

Table 4 Calculation of Target Load for Winter-Spring Flows				
Flow (cfs)	***Flow (mgd)***	Turbidity Std. (NTU)	***TSS target (mg/L)***	***Target Load, TSS (lbs./day)***
28.9[2]	18.9	10.0[3]	10.8[4]	**1702**

1 8.34 is a conversion factor to transform mg/L to lbs./day, the units are (lbs.)(L)/(mg)(10^6 gallons)

2 Average flow values during the Winter-Spring flows (Nov 1 – May 31), data appeared in Graph 1; average discharge from 1940-2000

3 Arizona Aquatic and Wildlife cold-water stream surface WQS for turbidity is 10 NTU

4 Calculated using Equation 1, Winter – Spring TSS vs. Turbidity, and inputting the turbidity value of 10 NTU

Calculation of Little Colorado River TMDL for Winter-Spring Flows

TMDL as TSS (lbs./day) = WLA + LA + BG + MOS

MOS + LA = TMDL — WLA—BG, but, *MOS = 0.10(LA)*

0.10(LA) + 1(LA) = TMDL — WLA—BG

LA = (TMDL — WLA—BG)*/(1.10)*

Table 5 Calculation of TMDL for Winter-Spring Flows				
WLA (lbs./day)	***LA (lbs./day)***	***Background (lbs./day)***	MOS, 10% (lbs./day)	***TMDL (lbs./day)***
0	**1225**	354[1]	123[2]	**1702**

1 This value was calculated earlier in section 2.3.2

2 MOS is 10% of the LA to accommodate for errors in data, graphical interpretations, and calculations of values

Calculation of the Measured** Load for Winter-Spring Flows

Flow (mgd) x ***Measured** TSS*** (mg./L) x 8.34[1] = ***Measured** Load, TSS*** (lbs./day)

Table 6 Calculation of Measured** Loads for Winter-Spring Flows				
Flow (cfs)	***Flow (mgd)***	Measured** Turbidity (NTU)	***Measured** TSS (mg/L)***	***Measured** Load, TSS (lbs./day)***
28.9[2]	18.9	27.8[3]	44.2[4]	**6959**

** The term "Measured" refers to average Winter – Spring high flow values which were estimated using the correlation graphs, and aren't representative of actual field measurements.

1 8.34 is a conversion factor to transform mg/L to lbs./day, the units are (lbs.)(L)/(mg)(10^6 gallons)

2 Average flow values during Winter-Spring flows as identified in graph 1

3 Calculated using Equation 1, TSS vs. Turbidity, and inputting the TSS value 44.2 mg/L

4 Calculated using Equation 2, Winter – Spring Discharge vs. Turbidity & TSS, and inputting a flow of 28.9 cfs

Calculation of TSS Load Reduction (lbs. per day) for Winter-spring flows

Measured** Load, TSS - Target Load, TSS = ***Load Reduction, TSS*** (lbs./day)

Table 7 Calculation of Load Reductions for Winter-Spring Flows		
Measured** Load, TSS (lbs./day)	***Target Load, TSS (lbs./day)***	***Load Reduction, TSS (lbs./day)***
6,959	**1,702**	**5,257**

** The term "Measured" refers to average Winter – Spring high flow values which were estimated using the correlation graphs and aren't representative of actual field measurements.

2.3.6 Summer-Fall Flow Based TMDL Values

The following TMDL calculations are based upon the average Summer-Fall flow value of 13.1 cfs. Recalculation of the TMDL values using the average flow value of 13.1 cfs also requires the use of the corresponding Summer – Fall correlations and equations.

Calculation of Target TSS Load, adjusted for Summer-Fall Flows

Flow (mgd) x ***TSS target*** (mg/L) x 8.34[1] = ***Target Load*** Capacity, TSS (lbs./day)

Table 8 Calculation of Target Load for Summer-Fall Flows				
Flow (cfs)	***Flow (mgd)***	Turbidity Std. (NTU)	***TSS target (mg/L)***	***Target Load, TSS (lbs./day)***
13.1[2]	8.5	10.0[3]	9.6[4]	**681**

1 8.34 is a conversion factor to transform mg/L to lbs./day, the units are (lbs.)(L)/(mg)(10^6 gallons)

2 Average flow values during the Summer-Fall flows (June 1 – Oct 31), data appeared in Graph 1; average discharge from1940-2000

3 Arizona Aquatic and Wildlife cold-water stream surface WQS for turbidity is 10 NTU

4 Calculated using Equation 3, Summer – Fall, TSS vs. Turbidity, and inputting the turbidity value of 10 NTU

Calculation of TMDL during Summer-Fall Flow conditions

TMDL as TSS (lbs./day) = WLA + LA + BG + MOS

MOS + LA = TMDL — WLA—BG *but, MOS =0.25LA)*

0.25(LA) + 1(LA) = TMDL — WLA—BG

LA = (***TMDL — WLA—BG***)/(1.25)

Table 9 Calculation of TMDL for Summer-Fall Flows				
WLA (lbs./day)	***LA (lbs./day)***	***Background (lbs./day)***	MOS, 25% (lbs./day)	***TMDL (lbs./day)***
0	**262**	354[1]	65[2]	**681**

1 This value was calculated earlier in section 2.3.2.

2 MOS is 25% of the LA to accommodate for errors in data, graphical interpretations, regressions, and calculations of values

Calculation of the Measured** Load for Summer-Fall Flow conditions

Flow (mgd) x ***Measured** TSS*** (mg/L) x 8.34[1] = ***Measured** Load, TSS*** (lbs./day)

Table 10 Calculation of Measured** Loads for Summer-Fall Flows				
Flow (cfs)	***Flow (mgd)***	Measured** Turbidity (NTU)	***Measured** TSS (mg/L)***	***Measured** Load, TSS (lbs./day)***
13.1[2]	8.5	36.7[3]	35.4[4]	**2509**

** The term "Measured" refers to average Summer-Fall high flow values which were estimated using the correlation graphs, and aren't representative of actual field measurements.

1 8.34 is a conversion factor to transform mg/L to lbs./day, the units are (lbs.)(L)/(mg)(10^6 gallons)

2 Average flow values during Summer-Fall flows as identified in graph 1

3 Calculated using Equation 3, Summer – Fall, TSS vs. Turbidity, and inputting the TSS value 35.4 mg/L

4 Calculated using Equation 4, Summer – Fall, Discharge vs. Turbidity & TSS, and inputting the avg. Summer – Fall flow of 13.1 cfs

Calculation of Load Reductions for Summer-Fall Flow conditions

Measured** Load, TSS - Target Load, TSS = Load Reduction, TSS (lbs./day)

Table 11 Calculation of Load Reductions for Summer-Fall Flows		
Measured** Load, TSS (lbs./day)	***Target Load, TSS (lbs./day)***	***Load Reduction, TSS (lbs./day)***
2,509	681	**1828**

** The term "Measured" refers to average Summer-Fall high flow values which were estimated using the correlation graphs, and aren't representative of actual field measurements.

2.4 Waste Load Allocations

No point sources for turbidity were found to be present on the LCR during ADEQ's sampling efforts and investigations. There have been no National Pollutant Discharge Elimination System (NPDES) permits issued for this section of the river system. Therefore, the WLA for all TMDL calculations is zero.

2.5 Load Allocations

Comparison of the different seasons indicates that the Winter-Spring season is responsible for more sediment delivery to the LCR than the Summer-Fall flows. LAs were based on the Winter-Spring TMDL values and subdivided by potential source. The potential sources were grouped into categories, based on field observations, to allow for smaller allocations. This will make it possible to set goals and judge the effectiveness of implementation plans. The values are presented in the following table.

Table 12 Load Allocations and Load Reduction Targets by Source

Type of potential source	Percent contributing to the TMDL Load Allocation	Load value (lbs./day TSS)	Percent Reduction in Loading	Load Reduction (lbs./day TSS)	Percent of total load reduction necessary as per the TMDL
Grazing Practices	60	4,175	75	3,132	60
Stream Channel Instabilities	15	1,044	65	679	13
Road Cuts	5	348	55	191	4
Golf Course	5	348	85	296	6
Streambed Load	5	348	55	191	4
Natural Conditions	10	696	0	0	0
TOTAL	***100%*** *(6,959)*	***6,959***	***N/A***	***4,420***	***85%*** *(5,257)*

The overall load reduction needed to comply with current Arizona WQSs is approximately 5,257 lbs./day of sediment during the critical Winter-Spring flows. However, the recently completed and approved Nutrioso Creek TMDL for turbidity contains an implementation plan that targets an overall reduction of approximately 837 lbs./day of sediment during the critical Spring flow. As Nutrioso Creek is tributary to the LCR, this load reduction was subtracted from the needed reduction in the LCR to 4,420 lbs./day.

3 IMPLEMENTATION

By focusing most of the implementation on the larger values obtained from the Winter-Spring relationships, it can be assured that compliance with the TMDL will lead to the LCR meeting and maintaining Arizona's surface WQSs for turbidity. Private landowners as well as state and federal land managers can apply for grants and seek assistance in securing finances and technical expertise in meeting and maintaining the goals set forth in this report. Possible TMDL implementation strategies include the following:

1. Increase education and public awareness to local landowners through outreach and watershed group activities
2. Create milestones for each BMP and project and evaluate effectiveness as necessary
3. Decrease stream velocities during critical flow events by:
   a) Increasing willow vegetation
   b) Placing stream grade stabilization structures
   c) Increasing the flood plain (i.e. adding point bars)
4. Decrease sheet flow and wind erosion contributions to tributaries and listed segments of the LCR by:
   a) Removing rabbitbrush
   b) Increasing density of grasses as land cover
5. Prevent stream channel down cutting and promote stabilization by:
   a) Removing cattle and wildlife from the stream channel during critical flow periods
   b) Allowing cattle to graze only in the dormant winter months, under a range management system
   c) Re-vegetating the stream channel
   d) Using stream restoration techniques to speed up recovery of stream corridor

3.1 Best Management Practices

A variety of BMPs can be utilized as part of the implementation strategy to reduce sediment loading to the LCR.

Cattle grazing in the riparian corridor could be confined to only the dormant winter months, which would allow the emergent plants in the spring to grow and take hold. It would also allow for a greater diversity of plant communities in the riparian corridor, which will help establish more protective cover for the erosive soils and act as stream energy dissipaters during higher flows. The BLM recommends winter grazing because the cattle's hoof action compacts soils and adds in nutrients. Also, the cattle will feed on the mature old growth allowing room in the spring for the new growth to occur and compete for resources (BLM,1989). The USFS recommends that winter grazing maintain adequate stubble height of the vegetation going into the spring growing season (ADEQ, 2000).

The USFS Apache-Sitgreaves is a primary landowner in the project area. They are committed to improving the land resources within their jurisdiction and have several projects ongoing within the watershed (ADEQ, 2000). Some of these projects include: reduced logging, road closures, and revisions in grazing allotments.

The Apache-Sitgreaves National Forest has already implemented, or plans to implement, a variety of BMPs on lands under their jurisdiction including: 1) reduced logging; 2) road closures – 40 miles of roads were closed as an erosional control measure in 1999; and 3) the forest instituted the following grazing allotment revisions:

- Adjusted cattle entry times and densities

- Since 1995, they have had a 66% reduction in cattle numbers on the Alpine District

- A goal to balance the permitted numbers with the allowable use by 2005 in all Apache-Sitgreaves National Forest Grazing Allotments

The management of ungulate wildlife populations is the jurisdiction of AGFD. For Game Management Unit (GMU) 1, in which this portion of the LCR watershed is located, elk population numbers have declined approximately 42% since 1994. The AGFD has implemented a monitoring program to assess herbaceous forage utilization by elk in key areas in all GMUs within Region I. This information enables the Department to incorporate habitat-based parameters into annual population management objectives for elk. The monitoring data indicated high utilization in localized areas of the LCR by elk. To address utilization concerns, the AGFD has proactively implemented management strategies during the last several years with the objective of reducing the elk population in GMU 1. As noted above, these strategies have resulted in substantial reductions since the mid-1990's. The success of these strategies is dependent on a variety of factors including habitat condition and available forage. The AGFD actively manages ungulate wildlife populations within the watershed. The AGFD monitors herbaceous forage usage of elk, the primary wildlife ungulate, to assist in population management strategies. Active management strategies enacted over the last several years have resulted in an approximate 42% reduction in the number of elk (AGFD, 2002).

The large sector of private lands also needs to be addressed. Additional projects and BMPs for use on private lands will be important in the future.

Several implementation practices and projects have been undertaken on Nutrioso Creek, a tributary to the LCR, that could be beneficial if applied to other areas within the LCR listed reach. Some of these projects include:

- In areas where historic overgrazing has occurred, private landowners have fenced off the riparian corridor to keep out cattle and elk during critical growing periods.

- Stream grade stabilization structures have been installed to help protect the at risk banks during high critical flow events. These structures will also help dissipate stream velocities and thus dissipate stream energy and erosional forces during high flows (ADEQ, 2000).

- Stream restoration projects have been undertaken to speed up the development of an in-channel flood plain, increase sinuosity, etc. It is important to note, while these projects have created a more immediate impact on improving water quality during critical flow, they are more costly and severe to implement.

- Off channel water wells and wildlife drinkers have allowed for more water to remain in the stream itself and allow for the riparian corridor to be fenced off without water-gaps for wildlife and cattle to access the stream for drinking purposes. This has allowed for irrigation of the re-vegetation projects along the stream corridor. However, caution should be used in the placement of these structures. While reducing water withdrawals from stream channels is commendable goal, a shift to groundwater use, if it results in an overall increase in water use, could result in a lowered water table, which could in turn negatively affect in-stream flows (AGFD, 2002).

- The riparian corridor has been re-vegetated with willow plantings and grass seeds using a Critical Area Planting method as outlined by the Natural Resources Conservation Service. These plantings have been supplemented with sprinkler irrigated waters until they took hold on the established banks and stream course. The plantings on the upland areas beyond the stream corridor were sprinkler irrigated until the root were established enough to reach the moisture in the soils. These plantings have helped protect the erosive soils and act to dissipate stream energy during critical flow (ADEQ, 2000).

- Sprinkler irrigation systems combined with a poly pipe to line the irrigation ditch have increased irrigation efficiencies and allowed for more water to stay in the stream and thus increase the streamflow year round. Combined with other projects and aspects of implementation these tools have allowed for effective revegetation and removal of cattle and wildlife from the stream course for the majority of the year by creating more forage in the managed rangeland and an alternative water source created from the groundwater wells.

- Rabbitbrush eradication projects have been undertaken on some properties. By removing the rabbitbrush and replacing it with grass seeding, more grass per acre has been created for cattle consumption, reducing their reliance on the riparian vegetation of the stream corridor and allowing for their removal from the riparian corridor with the use of fences and range management plans. From a watershed standpoint the removal of rabbitbrush and reintroduction of grasses improves species diversity and composition. Also, the grasses provide a more stable root mass than the rabbitbrush, thus increasing the soil stability of the rangelands and decreasing the amount of sediment contributed from sheet flow and wind erosion over these rangelands.

3.2 MONITORING PLAN

ADEQ staff will continue to monitor turbidity, TSS, flow, and stream morphology over the next several years during varied flow stages. The LCR watershed is scheduled for more intensive ambient monitoring as a part of the Fixed Station Network (FSN) rotating watershed approach in 2006. This approach targets two watersheds each year over a five year period. ADEQ will monitor water quality and physical integrity of the LCR using techniques such as :

- Historic photo monitoring sites that are present, which can be utilized for future comparisons.
- Aerial photography to monitor vegetative cover.
- Stream channel cross sections to assess changes in channel morphology.
- Permanent follow-up monitoring sites to perform trend analyses.

Macroinvertebrate sampling may also be undertaken in order to obtain the necessary information to calculate an Index of Biological Integrity score. This information will allow for a more direct measure of the health of the LCR aquatic ecosystem. This data will augment the turbidity and TSS data as it is a more direct measure of stream health for water designated as Aquatic and Wildlife cold (A&Wc). This data will also allow for the re-evaluation of the implementation strategies, milestones, and goals.

Potential volunteer monitoring of native threatened and endangered aquatic species and the displacement, or die-off, of introduced aquatic species would contribute valuable data. This could help to guide implementation, future BMPs, and the re-evaluation of this TMDL and the milestones set forth. Volunteer monitoring of discharge, turbidity, and TSS, along with erosional and sedimentation features, could be of assistance in the future for re-evaluation and assessment of the goals and values set forth, as well as to track progress of the implementation plan.

3.3 Time Line

The LCR TMDL will use a phased approach to TMDL implementation. Watershed projects will be started incrementally as they are funded. The time frame for implementation is estimated to be 10 years (Table 13). Therefore the timeframe estimated for the LCR to meet the turbidity standard during critical flows is approximately 15 - 30 years, depending upon the amount and the duration of flow events in the LCR. The USEPA recognizes that sediment TMDLs with primarily non-point sources of pollution can be difficult to manage, and that these problems are often generated over multiple generations and may require as long to correct (USEPA, 1999).

Table 13 Estimated Implementation Schedule

	YEAR									
ACTIVITY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Public outreach & involvement	X	X	X	X	X	X	X	X	X	X
Establish Milestones	X				X					X
Secure project funding, as needed	X	X	X	X	X	X	X	X	X	X
Best Management Practices	X	X	X	X	X	X	X	X	X	X
Determine BMPs effectiveness			X		X					X
Reevaluate Milestones and strategies					X					X

3.4 Milestones

Milestones will be used to determine if control measures and BMPs are having a positive impact on reducing turbidity and the erosional forces present in the LCR. Various measures will be utilized as milestones to measure the success of the projects and the BMPs. This could include an increased amount of natural vegetation in the stream course, a more stable channel geometry, lowered stream velocities, lower TSS and turbidity values during higher discharges, and more balanced TSS and turbidity values during different flow regimes. The milestones will be reevaluated periodically to determine their validity and effectiveness as more data is available for analysis.

3.5 Assurances

Arizona Revised Statutes do not provide for enforceable actions to be taken against non-point sources of pollution. Implementation plans for nonpoint source TMDLs depend solely upon the volunteer approach of land managers, in implementing projects and BMPs. Cooperation of State and Federal Agencies and private landowners will be paramount in the implementation of this TMDL. ADEQ has grant funding available, as do other agencies, to help with the implementation of watershed restoration strategies.

4 PUBLIC PARTICIPATION

4.1 Public Participation in the TMDL Process

Public participation occurred during data collection, background information, and in developing this report. In March 2002, the draft TMDL was made available for a 30-day public comment period. Public notice of the availability of the draft document was posted in a newspaper of general circulation (*The White Mountain Independent*), email notifications, phone calls, and webpage postings. The LCR TMDL Draft was presented to the Upper Little Colorado River Watershed Group in their March 28, 2002 meeting.

No comments were received during the public notice. This TMDL was published in the Arizona Administrative Register in May, 2002, in compliance with A.R.S. §49-231. After the 45-day notice period has been completed, the TMDL will be forwarded to EPA for approval.

4.2 Watershed Group

The LCR Watershed Partnership was formed in November of 1998. The LCR Watershed Partnership incorporates concerned private citizens, private landowners, and other interested State and Federal Agency personnel. The watershed group will provide oversight for the implementation projects and plans, and may provide additional data in the form of volunteer monitoring of the stream.

ADEQ has a website at http://www.adeq.state.az.us/environ/water/assess that will provide information and links to other data relevant to this LCR TMDL and contact information.

REFERENCES

ADEQ. Arizona's 1998 Water Quality Limited Waters List (Arizona's 303(d) List.) EQR-98-8 July 1998.

ADEQ. Nutrioso Creek TMDL. July 2000.

ADHS. The Little Colorado River Watershed above Lyman Lake: Water Chemistry, Nutrients, and Nutrient Standards. July 1982.

AGFD. Personal communication with John Kennedy. March 2002

Arizona State University. Department of Geology web page, http://geology.asu.edu/volc/az_volcs.

Bureau of Land Management. Grazing Management for Riparian-Wetlands Areas. TR 1737-11 1989.

Bureau of Land Management. Process for Assessing the Proper Functioning Condition. TR 1737-14 1997.

Bureau of Land Management. Process for Assessing the Proper Functioning Condition for Lentic Riparian-Wetlands Areas. TR 1737-6 1992.

Bureau of Land Management. Management Techniques in Riparian Areas. TR 1737-3 1989.

Bureau of Land Management. Managing Change –Livestock Grazing on Western Riparian Areas. July 1993.

Bureau of Land Management. Riparian Area Management. TR 1737-9 1993.

Hyde, Peter. ADEQ. Elevated Fecal Coliform Levels in LCR and the LCR at Eagar/Springerville, Apache County, May and June 1993. December 1994.

Reynolds, Stephen J. Geologic Map of Arizona. 1988.

Snyder, Bruce and Snyder, Janet. Engineering-Science, Inc. for ADEQ contract # 343280S25. Analysis of Water Quality Functions of Riparian Vegetation. Oct. 1994.

USEPA. Protocol for Developing Sediment TMDL's, 1st Edition. EPA 841-B-99-004 October 1999.

APPENDIX A

STATION NUMBER	DATE	TURBIDITY VALUE (NTU)	AVG. TURB. (NTU)	FLOW(CFS)	TSS(MG/L)
100329	08/21/90	1	1	1.74	5
	10/19/90	0.8	0.8	2.46	4
	06/19/91	1.32	1.32	23.52	6
	08/07/91	1.38	1.38	4.6	5
	10/09/91	0.49, 0.46	0.48	2.89	4
	01/06/92	0.58	0.58	6.5	4
	04/15/92	8.30, 10.00	9.15	6	4
	06/10/92	2.10, 2.50	2.3	20.76	7
	08/11/92	2.20, 1.05	1.63	6.15	10
	10/18/94	0.79, 1.07	0.93	4.2	4
	12/13/94	0.16, 0.16	0.16, 0.16	6	4
	04/18/95	2.70, 3.48	3.09	8.9	9
	06/07/95	1.50, 4.48	2.99	37.62	12
	08/29/95	3.3	3.3		
100328	11/11/87	1.55	1.55	8.42	5
	01/13/88	0.71	0.71	5.54	2
	02/17/88	3.8	3.8	5.77	2
	04/12/88	3.9	3.9	17.79	5
	06/22/88	0.96	0.96	12.13	8
	09/14/88	1.9	1.9	13.2	5
	10/18/88	0.9	0.9	6.1	14
	11/08/88	0.8	0.8	5.7	4
	12/13/88	1.1	1.1	5.3	2
	01/09/89	1.4	1.4	5.7	8
	02/15/89	0.71	0.71	3.9	2
	04/10/89	4.2	4.2	12.9	26
	05/08/89	2.5	2.5	11.6	4
	06/06/89	0.4	0.4	5.1	2
	07/10/89	0.83	0.83	3.9	10
	07/31/89	1.7	1.7	5.6	4
	09/14/89	0.9	0.9	7.9	4
	10/26/93	0.65, 1.2	0.93	6.62	4
	12/15/93	1.1, 1.68	1.4	5.78	4
	02/10/94	0.97, 1.38	1.18	5.27	4
	04/13/94	1.39, 1.87	1.63	7.74	4
	06/14/94	1.2, 2.1	1.7	9.81	4

Station Number	Date	Turbidity Value (NTU)	Avg. Turb. (NTU)	Flow(cfs)	TSS(mg/L)
100328 cont	08/16/94	1.23, 1.88	1.56	6.16	4
	10/18/94	0.78, 1.6	1.19	5.16	4
	12/13/94	0.23, 2.2	1.22	6.27	4
	02/22/95	2.9, 5.13	4	7.31	9
	04/18/95	3.2, 3.74	3.5	22.1	7
	06/06/95	2.1, 4.62	3.4	41.33	10
	08/28/95	1.33, 3.41	2.37	17.08	5
	10/30/95	0.63, 1.94	1.29	5.48	4
	12/27/95	0.79, 3.47	2.13	5.53	4
	02/22/96	0.93, 1.41	1.17	4.88	4
	04/26/96	0.47, 3.20	1.84	5.53	4
	06/18/96	0.86, 1.25	1.06	2.5	4
	08/28/96	1.21, 1.19	1.2	4.88	7
	04/13/99	6.97, 3.10	5.04	6.94	
	06/22/99	0.71, 1.54	1.13	4.64	
	08/24/99	2.13, 1.00	1.57	14.35	
	10/14/99	1.36, 0.97	1.17	5.28	4
	03/30/00	2.00, 2.60	2.3	5.67	
	06/28/00	5.40, 2.70	4.05	5.53	10
0	06/20/00	11, 13.4	12.2		
	08/01/00	12.2, 12.4	12.3	0.31	20
	09/27/00	5.52, 5.63	5.75	0.52	13
	10/24/00	4.56, 3.48	4.02	0.85	10
10	06/20/00	3.24, 3.99	3.62		
	08/01/00	3.89, 6.04	4.97		
	09/27/00	7.9, 6.75	7.33		16
	10/24/00	8.11, 7.9	8.01		6
100644	07/08/92	0.6, 0.4	0.5	5	
	06/16/93	0.8, 1.5, 0.6	1		
	06/08/95	1.7	1.7	0.3	
	06/02/98	0.94, 0.95	0.9		
20	06/20/00	1.27, 1.32	1.3		
	08/01/00	1.04, 1.41	1.23		
	09/27/00	0.32, 0.65	0.49	1.43	8
	10/24/00	2.77, 2.71	2.74	0.83	
22	06/20/00	3.23, 2.88	3.06		
	08/01/00	2.64, 2.09	2.37		

Station Number	Date	Turbidity Value (NTU)	Avg. Turb. (NTU)	Flow(CFS)	TSS(MG/L)
22 CONT	09/27/00	1.99, 1.94	1.97		9
	10/24/00	2.08, 2.48	2.28		8
30	06/20/00	7.05, 6.42	6.61		
	06/21/00	5.91, 5.73		8.31	6
	06/23/00	6.46, 6.76		8.3	6
	08/01/00	7.35, 6.72	7.04	4.66	4
	09/27/00	5.96, 5.76	5.86	2.01	10
	09/28/00	8.37, 8.24	8.31		
	10/24/00	7.52, 7.7	7.61	5.45	18
35	06/20/00	12.1, 12	12.05		
	08/01/00	24.3, 24.2	24.3		17
	09/27/00	33, 31.8	32.4		36
	10/24/00	24, 24.2	24.1		27
40	06/20/00	27.4, 27.9	27.7		
	08/01/00	30.4, 32.3, 33.2, 29.4	31.3	4.24	30
	09/27/00	23.6, 22.9	23.25	0.73	21
	10/24/00	31.5, 31.7	31.6	7.22	32
52	06/23/00	14.2, 13.2	13.7	9.34	24
	06/21/00	18.6, 18.5	18.6	6.89	5
	08/01/00	29.4, 27.9	28.7	3.78	23
	09/27/00	14.7, 13.7	14.2	1.53	14
	10/24/00	27.3, 26.4	26.85		21
70	06/21/00	17.9, 17.8	17.9		
	08/03/00	38, 36.2	37.1		
	09/27/00	15, 15.7	15.35		
	10/24/00	29.3, 27.8	28.55		34
76	06/21/00	14.5, 14.3	14.4		
	08/03/00	34.9, 34.7	34.8		
	09/27/00	15.1, 15.1	15.1		
	10/24/00	29.8, 29	29.4		33
78	06/21/00	14, 14.7	14.4		
	08/03/00	33.9, 32.8	33.4		
	9/27/00	14.4, 14.8	14.6		24
	10/24/00	28.6, 29.1	28.85		47
80	06/21/00	28, 27.5	27.8		
	08/02/00	31.9, 30.5	31.2		
	09/27/00	16.4, 16.8	16.6		12

Station Number	Date	Turbidity Value (NTU)	Avg. Turb. (NTU)	Flow(CFS)	TSS(mg/L)
80 cont	09/28/00	23, 22.6	22.8		
	10/25/00	26.6, 26.3	26.45		25
90	06/21/00	25.5, 24.4	25	2.31	26
	06/23/00	21.2, 24.7	23		
	08/02/00	39.9, 39.4	39.7	1.44	38
	09/27/00	31.6, 31.4	31.5	0.84	47
	10/24/00	46.1, 46.7	46.4		50
100333	10/26/93	6, 12.3, 6.3	8.2	4.94	8
	12/15/93	7, 7.06	7.03	1.78	4
	02/10/94	5.5, 8.47	7	2.98	6
	04/14/94	11.2, 12.7	12	15.07	14
	06/02/94	8.7	8.7	2.66	15
	06/14/94	8.6, 11.3	10	2.58	9
	10/18/94	7.4, 9.99	8.7	7.15	5
	12/13/94	3.5, 13.7	8.6	6.49	10
	02/22/95	11.2, 15.6	13.4	13.99	11
	04/18/95	7.2, 7.83	7.5	28.93	11
	06/06/95	8.7, 11.5	10.1	6.78	19
	08/29/95	53, 96.4	74.7	40.1	130
	10/30/95	9.4, 13.2	11.3	4.378	12
	12/27/95	6, 10	8	5.97	12
	02/22/96	11.3, 18.3	14.8	4.11	18
	04/24/96	12.2, 16.1	14.2	1.58	19
	06/20/96	7.3, 11.3	9.3	0.8	12
	08/28/96	22 ,38.3	30.15	4.55	53
100331	06/19/91	6.6	6.6	14.19	7
	08/07/91	14.4	14.4	8.98	29
	12/03/91	3.9, 6.3	5.1	1.17	14
	10/09/91	9.4	9.4	0.25	16
	02/19/92	6.2			
	06/11/92	43	55	17.12	21
	08/11/92	12.5, 14	13.3	10.28	38
	11/24/92	16.4, 24.5	20.5	7.12	14
	03/16/93	46.5, 9.2	27.9	77.2	126
	06/23/93	14.6, 47	30.8	13.14	17
	04/13/99	7.9, 16.3	12.1	2.92	11
	06/22/99	12.2, 7.3	9.8	2.16	5

STATION NUMBER	DATE	TURBIDITY VALUE (NTU)	AVG. TURB. (NTU)	FLOW(CFS)	TSS(MG/L)
100331 CONT	08/24/99	16.4, 10	13.2	36.72	16
	10/14/99	9.51, 5.2	7.4	5.5	7
	03/29/00	19, 22.6	20.8	14.53	40
	06/28/00	10.2, 6.7	8.5	1.35	8
	08/15/00	24, 44.5	34.3	2.18	42
100	06/21/00	9.96, 10.7	10.3		
	08/02/00	40, 38.8	39.4	1.46	27
	09/28/00	34.8, 33.8	34.3	1.07	41
	10/24/00	79.7, 76.9	78.3	7.93	60
108	09/27/00	41, 41.7	41.35		
	10/24/00	78, 74.3	76.15		63
109	08/02/00	32.9, 33.1	33	1.45	27
	09/27/00	38.3, 39.1	38.7	0.63	29
	10/24/00	71.4, 71.4	71.4	8.11	66
110	06/21/00	35.8, 34.4	35.1		
	09/27/00	51.3, 51.8, 56.7, 59.2	51.55, 57.95	0.56	
	10/24/00	76.2, 77.3	76.75		65
120	08/02/00	36.9, 35.5	36.2	0.85	32
	09/28/00	45.6, 46.2	45.9	0.21	45
	10/24/00	86, 85.3	85.65	9.13	66
130	06/22/00	33.5, 33.6, 34.6, 34.6	34.1		
	08/02/00	35.5, 33.5	34.5		
	09/28/00	35.9, 36.2	36.05		
	10/24/00	127, 128	127.5		110
140	06/21/00	28.9, 29.3	29.1		
	08/02/00	33.7, 32.6	33.2	1.16	32
	09/28/00	16.7, 16.5	16.6	0.88	
	09/28/00	26.9, 27.9	27.4		15
	10/24/00	108, 101	104.5	10.25	91